INVESTIGATOR'S ANNUAL REPORT

National Park Service

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Permit#:
SHEN-1999-SCI-0002

Park-assigned Study Id. #:
SHEN-00277

Project Title:
Characterization of Metamorphism and Tectonic Setting of Grenvillian Rocks in the Western Blue Ridge, Virginia

Permit Start Date: Sep 01, 1999	**Permit Expiration Date** May 31, 2004
Study Start Date: Sep 01, 1999	**Study End Date** May 31, 2004

Study Status:
Continuing

Activity Type:
Research

Subject/Discipline:
Geochemistry (inc. Minerals / Petrology)

Objectives:

Grenville-age rocks in the western Blue Ridge terrane in Virginia consist of a layered metamorphic sequence, characterized by granulite-facies mineral assemblages, intruded by charnockite (two-pyroxene granite) and anorthosite plutons. This plutonic-metamorphic terrane constitutes the former rifted Laurentian margin of North America, much modified during Paleozoic orogenic events. Other than basic lithologic descriptions and some geochronology, relatively little is known about the metamorphic basement rocks into which Grenvillian plutons were intruded. The depths of intrusion of the charnockites and anorthosites are unknown and the timing of intrusion relative to granulite metamorphism is poorly constrained, although granulite-facies metamorphism in northern Appalachian Grenville terranes is known to postdate the intrusions. Emplacement of such plutons is believed to have occurred at shallow depths (5-10 km) and low pressures (2-3 kbars), however, arguments have been made, based on the presence of Fe-rich orthopyroxenes in charnockites, that some of these plutons might have been emplaced at significantly greater depths (e.g. Ollila et al., 1988, American Mineralogist).

At present, systematic variation in the tectonic setting of Grenvillian terranes from different parts of the Appalachians has not been documented. This proposed study will address this by investigating the interactions of Grenvillian plutons with metamorphic basement through the use of petrologic, thermobarometric, and geochronologic techniques in order to better constrain the tectonic and metamorphic histories of the western Virginia Blue Ridge and to document any significant differences from other Grenvillian terranes within the Appalachians.

The goals of this project are to produce: (1) a detailed characterization of western Blue Ridge basement lithologies, (2) a quantitative evaluation of the metamorphic processes that have affected these lithologies, and (3) a determination of the extent and nature of interaction of these rocks with Grenvillian plutons. Detailed mapping and petrographic observations will be used to search for evidence of preserved contact aureoles around Grenvillian intrusions. Intrusion of charnockites and anorthosites into rocks at lower than granulite-facies grade would have produced high-T (potentially 800-1000 C) metamorphic assemblages in contact aureoles that should not have been completely overprinted by a later, somewhat lower-grade (700-800 C), regional granulite-facies event. Even if the basement had already experienced a high-grade (granulite-facies) event prior to intrusion and obvious contact aureoles were not formed, some observable textural and mineral-chemical modifications would have occurred adjacent to igneous

contacts. The primary analytical technique to be employed in this study will be electron microprobe analysis, for (1) acquiring chemical data to be used for P-T estimations by published thermobarometric techniques, and (2) dating metamorphic and igneous monazites using trace-element analyses of U, Th, and Pb in an exciting new technique for microprobe-based geochronology. This method has advantages over geochronology by traditional U-Pb mass spectrometry because it allows for the resolution of multiple metamorphic events that may have been preserved in narrow zones within individual monazite crystals.

This project ultimately should produce results that are useful at two scales. Preserved contact aureoles documented by paleothermal or petrographic evidence will be used, along with geochronologic and geobarometric data, to constrain crustal depths, timing, and the nature of country rocks in the Proterozoic intrusive event. In addition, thin-section scale observations of the contact zones will provide valuable information on mid- and deep-crustal intrusive and metamorphic mechanisms.

Findings and Status:

Granulite and charnockitesamples from the Blue Ridge Parkway, Shenandoah National Park and areas adjacent to park boundaries were examined in the following ways:

1) Petrographic descriptions and chemical analyses of minerals (specifically pyroxenes)using the electron microprobe and two-pyroxene temperature estimations from this data.

The pyroxenes in these rocks consist of augite and inverted ferropigeonite. Inverted pigeonite is the more abundant of the two pyroxenes, making up about 10% of the mode, while augite is generally less than 5%. Exsolution lamellae of augite in the host inverted ferropigeonite (now orthopyroxene) and of ferropigeonite in the host augite are evident in both false-color electron microprobe images and in optical observations of these pyroxenes in thin section. Compositions of the original high-temperature pyroxenes were reintegrated using estimations of the relative amounts of lamellae and host from electron microprobe images of Ca concentration. Reintegrated compositions of ferropigeonite range from Wo13.6 En37.0 Fs49.4 to Wo20.5 En25.0 Fs54.5 and those of reintegrated augite range from Wo37.6 En32.7 Fs29.7 to Wo36.6 En26.6 Fs36.9. Temperatures were determined by applying the reintegrated compositions of coexisting pyroxenes to the QUILF thermometer (Anderson et al., 1993, Comp. and Geosci.) Resulting temperatures were all in excess of 900 degress Celcius, suggesting that they represent magmatic intrusion temperatures rather than temperatures reached during Grenvillian granulite-facies metamorphic event.

2) Th-U-total Pb chemical dating using the electron microprobe.

Igneous and granulite-facies metamorphic rocks of the western Blue Ridge Terrane (Pedlar Terrane) in central Virginia clearly show Grenvillian ages (ca. 1000 ¿ 1050 Ma), based on published traditional U-Pb zircon geochronology. However, these rocks were subjected to multiple younger thermal events during Paleozoic tectonic activity in the central Appalachians. Chemical dating of monazites in these high-grade rocks by electron microprobe analysis allows this complex thermal history to be deciphered. This method provides greater resolution than traditional geochronological methods because it allows for in-situ analysis of very small areas (~ 2 micon diam.) of individual, commonly complexly¿zoned, monazite grains.

Despite these advantages, there are some drawbacks with applying this method to the rocks of the Blue Ridge. Monazite is a fairly rare accessory mineral in these rocks. When present, it occurs as relatively very small grains, most being substantially less than 50 microns in diameter. In addition, low concentrations of Th, U, and Pb in the monazite leads to substantial errors in the calculated ages.

However, several samples did yield monazite with sufficient amounts of Th, U and PB to allow for calculation of ages. Ages calculated from electron microprobe data span a wide spectrum from 450 Ma to over 1050 Ma. Ages commonly do not vary across chemical zones. The majority of data clearly define a Grenville age (1000 20 Ma) for the apparent initial crystallization of monazite. The remainder of the data indicate partial reequilibration and age resetting during later thermal events, particularly along some (but not all) margins and along fractures. Absence of ages younger than about 450 Ma suggests that well known younger tectonic events, such as the stacking of Alleghenian thrust slices, are probably not recorded by the monazite. A group of ages around 970-950 Ma may be a post-Grenville thermal event, though there is insufficient data at this time to confirm this.

3) Initial petrographic examination of garnet-bearing samples reveals that garnet is commonly in symplectic relationships with orthopyroxene and biotite. Electron microprobe analyses and thermobarometric estimations of these textures are currently in progress.

For this study, were one or more specimens collected and removed from the park but not destroyed during analyses?

Yes

Funding provided this reporting year by NPS:	**Funding provided this reporting year by other sources:**
0	0

Fill out the following ONLY IF the National Park Service supported this project in this reporting year by providing money to a university or college

Full name of college or university:	**Annual funding provided by NPS to university or college this reporting year:**
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